04129US FLOW SENSOR IN A HOUSING

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the priority of Swiss patent application 1644/00, filed August 23, 2000, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

The invention relates to a flow sensor having a housing and a semiconductor chip with integrated sensor.

A known flow sensor of this type comprises a two part housing forming a measuring conduit. A semiconductor chip with a sensor is arranged at a wall of the measuring conduit. For sealing the conduit, the semiconductor chip is clamped between the housing sections.

This known solution has, however, the disadvantage that it is not suited for applications where there is a high static or dynamic pressure in the measuring conduit.

BRIEF SUMMARY OF THE INVENTION

Hence, it is a general object of the invention to provide a flow sensor with a housing which is able to withstand high pressure.

Now, in order to implement these and still further objects of the invention, which will become more readily apparent as the description proceeds, the flow sensor is manifested by the features that it comprises a housing with

at least two housing sections and forming a measuring conduit between at least some of said housing sections, a semiconductor chip comprising a sensor arranged at a wall of the measuring conduit, a sealing ring arranged between two housing sections and surrounding said semiconductor chip, said sealing ring pressing against a support formed by at least one of said housing sections, and at least one strip conductor connected to the semiconductor chip and extending between said support and said sealing ring and out of said housing.

In such an arrangement, the semiconductor chip has no sealing function but is completely arranged in the area enclosed by the sealing ring. For connecting the semiconductor chip, one or more strip conductors are lead out of the housing, passing between the support and the sealing ring. Such a device can be assembled easily.

Preferably, the at least one strip conductor is arranged on a flexible support foil. It is, however, also possible to arrange the strip conductor on one of the housing sections.

Preferably, the measuring conduit is formed by a groove in the surface of a first housing section. For connecting the groove, connecting ducts can be provided, e.g. in the form of bores or holes, which extend through one or several housing section(s). The sealing ring can be arranged around the groove. This arrangement allows to seal the conduit from all sides.

Preferably, the semiconductor chip is arranged in a recess of the second housing section and its top surface (i.e. the side with the sensor) is flush with the wall of the measuring conduit in order to favour laminar flow within the conduit. For exactly positioning the top surface of the semiconductor chip, it is in contact with the first housing section. Preferably, a spacer is arranged at the bottom of the

recess, which spacer is deformed by the force exerted by the first housing section on the semiconductor chip. In this way, an accurate alignment of the sensor element with the measuring conduit is guaranteed when the device is assembled. The spacer can e.g. be formed by small bumps at the bottom of the recess.

The flow sensor according to the present invention is suited for measuring the flow of fluids at normal and elevated pressure.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood and objects other than those set forth above will become apparent when consideration is given to the following detailed description thereof. Such description makes reference to the annexed drawings, wherein:

Fig. 1 is an exploded view of a first embodiment of the flow sensor,

Fig. 2 is the first housing section as seen from the second housing section,

Fig. 3 is the second housing section as seen from the first housing section,

Fig. 4 is a sectional view perpendicular to the measuring conduit through the flow sensor and the semiconductor chip,

Fig. 5 is a partial section of a possible embodiment of the semiconductor chip,

Fig. 6 is a sectional view of a second embodiment of the flow sensor,

Fig. 7 is a sectional view of a third embodiment of the flow sensor, and

Fig. 8 is a sectional view of a fourth embodiment of the flow sensor.

DETAILED DESCRIPTION OF THE INVENTION

The flow sensor shown in the figures comprises a first housing section 1, a second housing section 2 and a semiconductor chip 3 held between the housing sections 1, 2. Fig. 1 shows these parts at a distance from each other - in the assembled device, the housing sections 1, 2 are adjacent and semiconductor chip 3 is clamped between them.

A straight groove 5 is arranged in a surface 4 of first housing section 1. Groove 5 forms, together with adjacent second housing section 2, a measuring conduit. Two connecting ducts 6, in the forms of bores or openings, extend though second housing section 2 and communicate with the ends 5a, 5b of the measuring conduit. At the outer side of second housing section 2 the mouths of the connecting ducts 6 are surrounded by sealings 7 such that they can e.g. be connected with a tube carrying the fluid to be measured.

A possible set-up of semiconductor chip 3 is shown in Fig. 5. It comprises a semiconductor substrate 10 with a sensor element integrated on its top side 11. The sensor element has a conventional design with a heater 12 arranged between two temperature sensors 13a, 13b. The temperature sensors 13a, 13b are, when seen along the flow direction of the fluid to be measured, in front of and after heater 12, such that their temperature difference depends on the flow velocity or mass flow of the fluid.

The sensor element is located on a membrane 15, which extends over an opening 16 extending through substrate 10.

As can best be seen from Figs. 3 and 4, semiconductor chip 3 of a first embodiment of the invention is located in a recess 20 of the otherwise flat inner surface of second housing section 2, wherein the sensor element is facing the measuring conduit. Semiconductor chip 3 is connected to a flexible support foil 9 carrying strip conductors 9′ and extending out of the flow sensor's housing. For this purpose, a recess 22 is provided in second housing section 2. Support foil 9 is e.g. a thin plastic foil having a total thickness of preferably less than 100 μm, including the strip conductors 9′. The strip conductors are flat in order to avoid an excessive deformation of the sealing ring mentioned below.

A nose 23 is arranged between recess 22 and groove 5 and rests against semiconductor chip 3. Four pyramidal bumps 21 are located at the bottom of recess 20. Second housing section 2 presses semiconductor chip 3 against the bumps 21, thereby deforming the tips of the bumps and guaranteeing that semiconductor chip 3 is flush with the wall of the measuring conduit.

The bumps 21 are preferably an integral part of second housing section 2. They do not have to be pyramidal, but they should taper to a tip in undeformed state such that the tips can be deformed easily. They can be deformed in elastic or plastic manner.

Recess 20 has two lateral walls 26a, 26b parallel to the measuring conduit and two end walls 27a, 27b perpendicular to the measuring conduit. One of the lateral walls, 26a, ends in recessed sections 28a, 28b and extends straight therebetween for forming a well defined stop, which allows to position semiconductor chip 3 in exact manner perpendicular to the measuring conduit. Without the recessed sections 28a, 28b the corners between wall 26a and walls 27a,b would be

slightly rounded and semiconductor chip 3 would abut against these corners in an undefined manner.

Recess 20 is dimensioned such that gaps remain between end walls 27a, 27b and semiconductor chip 3 such that the area between semiconductor chip 3 and the bottom of recess 20 are communicating with the measuring conduit. This ensures that both sides of membrane 15 are in contact with the measuring conduit, such that the pressure drop over membrane 15 is substantially zero. This prevents membrane 15 from being damaged by high static or dynamic pressure peaks.

As can be seen from Figs. 1, 2 and 4, a recess 30 in first housing section 1 having the shape of an elongate circle extends around groove 5. A sealing ring 31 in inserted in recess 30. When the device is assembled, sealing ring 31 is pressed against the inner side of second housing section 2, thereby sealing the measuring duct in the gap between the housing sections 1, 2.

Since second housing section 2 absorbs the force generated by sealing ring 31, it is designated to be the support of the device.

Support foil 9 with the strip conductors 9' is led from semiconductor chip 3 between sealing ring 31 and the inner side of second hosing section 2. It is in contact with sealing ring 31. For better sealing action, a sealant paste 32, such as silicone, can be arranged between support foil 9 and sealing ring 31.

As can be seen from Fig. 2, semiconductor chip 3 is not arranged in the center of groove 5. Rather, it is located closer to exit end 5b than to entry end 5a. Since the fluid to be measured flows from entry end 5a to exit end 5b, the asymmetric arrangement of semiconductor chip 3 closer to exit end 5b leads to are more laminar flow at the point of measurement.

The housing sections 1, 2 are preferably fabricated by mould injection techniques. Then, sealing ring 31 is positioned in recess 30 and semiconductor chip 3 is inserted in recess 20. Sealing paste 32 is applied over strip conductor 9. Finally, the housing sections 1, 2 are stacked on each other and connected by means of screws inserted into holes 34.

The housing sections 1, 2 can be made from plastic and/or metal. In particular for high pressure, the housing can also be an assembly of metal and plastic, the metal providing the required stability and the plastic being provided at the inner surfaces where good sealing and deformation properties are desired. In particular, sealing ring 31 can also be a sealing rib injection moulded directly into one of the housing sections.

In the present embodiment, the connecting ducts 6 are located in second housing section 2. One or both of them can, however, also be located in first housing section 1. Furthermore, sealing ring 31 can also be mounted in second housing section 2, or there could be a sealing ring in each of the housing sections 1 and 2.

A second embodiment of the sensor is shown in Fig. 6, which shows a sectional view corresponding to Fig. 4 of the first embodiment. In the following, only the differences between the first and second embodiment are mentioned.

In the second embodiment, no support foil 9 is used. Rather, the strip conductors 9′ are mounted to the inner side of second housing section 2.

In order to avoid electrical connections between the strip conductors, second housing section 2 is made from an electrically isolating material or provided with an isolating coating at its inner side. The strip conductors 9′ are strips of metal, e.g. coated galvanically to second housing

section 2. Bond wires 35 or other connections can be used for connecting semiconductor chip 3 and strip conductors 9′. Outside the housing the strip conductors 9′ form connecting pads 36, which can e.g. be connected to leads or pins.

A third embodiment of the sensor is shown in Fig. 7, which also shows a sectional view corresponding to Fig. 4 of the first embodiment. Again, only the differences to the first and second embodiment are mentioned.

In this embodiment, the support foil has been replaced by a printed circuit board 2a carrying the strip conductors 9′. The backside of printed circuit board 2a is reinforced by a reinforcing plate 2b. Printed circuit board 2a and reinforcing plate 2b together form second housing section 2. Reinforcing plate 2b forms the support receiving the force of sealing ring 31.

Recess 20 for receiving semiconductor chip 3 is arranged in printed circuit board 2a. Preferably, a glue 38 is used for fixing semiconductor chip 3 to printed circuit board 2a, in such a manner that the backside of membrane 15 is sill communicating with the measuring conduit for preventing a pressure drop of the membrane. Again, bond wires 35 or other connectors are used for connecting semiconductor chip 3 to the strip conductors 9′, and the strip conductors form contact pads 36 at the outside of the housing.

Preferably, the strip conductors 9′ of the second and third embodiment are as thin as the support foil of the first embodiment and their thickness is less than 100 μm.

Sealing ring 31 is pressed against reinforcing plate 2b, which thereby acts as a support. Printed circuit board 2a extends between sealing ring 31 and reinforcing plate 2b.

A fourth embodiment of the sensor is shown in Fig. 8, which also shows a sectional view corresponding to

Fig. 4 of the first embodiment. The fourth embodiment corresponds substantially to the third embodiment. The differences are discussed in the following.

In the fourth embodiment, printed circuit board 2a is provided with strip conductors 9′ and 9″ on both sides. Semiconductor chip 3 is connected, e.g. via bond wires 35, with the strip conductors 9′ at the bottom side of printed circuit board 2a. The strip conductors 9′ end at feedthroughs 39, where they are connected to the strip conductors 9″ at the top side of printed circuit board 2a. The strip conductors 9″ extend between reinforcement plate 2b and sealing ring 31 to the outside of the housing where they form the contact pads 36.

The feedthroughs 39 are filled with a sealant 40 preventing a pressure leak from the measuring conduit.

The sensor described here can easily receive a pressure of more than 25 bar in the measuring conduit. It can be used for measurements of gases and liquids of any type.

While there are shown and described presently preferred embodiments of the invention, it is to be distinctly understood that the invention is not limited thereto but may be otherwise variously embodied and practised within the scope of the following claims.